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Acoustic Velocity Profiling in SYNOP
Principal Investigator: William E. Johns
Grant No.:N00014-89-J1139

The observational program in SYNOP consisted of three primary moored instrument arrays deployed in the Gulf Stream between Cape Hatteras and 55°W, complemented by regional and process-oriented studies using acoustically tracked floats and shipboard observations. One of the moored arrays, called the SYNOP "Central" Array, consisted of 13 tall current meter moorings and 24 inverted echo sounders (IESs) located within a 3° x 3° area centered near 37.5°N, 68.5°W. This location is just upstream of the surface eddy kinetic energy maximum in the Gulf Stream system, but in a region where large meanders continue to amplify rapidly and where frequent interactions between the Gulf Stream and adjacent warm and cold-core rings occur. The principal objectives of this array were (1) to document the structure, transport, and variability of the Gulf Stream at this location, (2) to map the evolution of the current and density fields at sufficient horizontal resolution to carry out meaningful diagnostic studies of mesoscale momentum and vorticity balances, and (3) to collect long enough in-situ records to obtain robust statistics on eddy-mean flow energy transfers related to nonlinear Gulf Stream instability mechanisms.

ONR Contract N00014-89-J1139, "Acoustic Velocity Profiling in SYNOP", supported the development of upward looking Acoustic Doppler Current Profilers (ADCPs) within the SYNOP Central Array to obtain long time series of the upper ocean currents, and subsequent analysis of the data. Technical results from the program regarding the use of upward-looking ADCPs to sample strong near-surface flows were very encouraging. Analysis of the data showed that ADCP velocity profiles accurate to 2 cm/s were obtained almost continuously to within 50 m of the surface (from nominal depths of 400 m) over a broad range of physical of backscattering conditions across the Gulf Stream (Johns, 1988; Johns and Zantopp, 1991). The technical goals of the program were therefore met, demonstrating an operational capability for measuring continuous, high-resolution current profiles for extended durations in a very demanding near-surface ocean environment.

The ADCP and conventional current meter data from the Central Array were merged together to form a detailed picture of the average Gulf Stream structure near 68°W, using an approach referred to as "stream-coordinate" analysis (Johns et al., 1995). Enhancements to this technique developed as part of this study allowed the results to be extended to the adjacent recirculation regions north and south of the Gulf Stream.

The mean synoptic transport of the Gulf Stream near 68°W was determined to be 113 Sv, as compared to an Eulerian mean transport of 88 Sv, the difference being due to the effects of meandering in the presence of large flanking recirculations. An important outgrowth of this analysis was the finding of an unexpectedly large westward recirculation north of the Gulf Stream near 68°W, from which it was concluded that the transport increase of the Gulf Stream between 73°W and 68°W is fed primarily by northern inflow, and that over half of the total Gulf Stream transport increase between Cape Hatteras and 68°W, approximately 30 Sv, is supplied by northern recirculation.

Variations in the synoptic structure of the Gulf Stream at 68°W were found to be only about 50% larger than those observed near Cape Hatteras, despite the nearly tenfold increase in meander-related path variance. Using a streamwise correlation analysis, the decorrelation time scale for structural variations was found to be about 10 days,

similar to the Eulerian time scale dominated by meandering. Low-frequency variations in Gulf Stream transport over the 2-year observation period ranged from 90 to 150 Sv, due mainly to variable barotropic component that appears to be closely linked to the development of large amplitude, quasi-stationary meander events in the region.

The stream-coordinate analysis technique was also applied to a study of the seasonal transport variability of the Gulf Stream. The results for the 26-month long Central Array deployment suggest a large deep-reaching baroclinic transport cycle with an annual range of nearly 20 Sv, characterized by a weak summer maximum and a prominent fall minimum. This finding is largely consistent with a recent reanalysis of historical hydrographic data across the Gulf Stream, and a paper describing these results, and comparing them with numerical model results, is in preparation.

In a parallel effort, an interdisciplinary physical-biological program (BIOSYNOP) was carried out to investigate biological features in the Gulf Stream frontal zone and their response to physical processes associated with Gulf Stream meandering. Backscatter measurements from Acoustic Doppler Current Profilers, when appropriately calibrated, have been shown to provide useful information on biomass variability of local zooplankton/micronekton populations. Backscatter data from the Central Array ADCP's was calibrated and transferred to BIOSYNOP investigators. Results from a preliminary analysis of the ADCP acoustic backscatter data (Spindler *et al.*, 1992) showed an obvious frontal enhancement of zooplankton biomass in a zone extending approximately 50-80 km shoreward from the Gulf Stream's North Wall.

Publications related to or citing ONR Grant N00014-89-J1139:

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Johns, W. E., T.Shay, J.M. Bane and D.R. Watts: Gulf Stream structure, transport, and recirculation near 68°W. *J. Geophys Res.*, **100**(C1), 817-838, 1995.

Hogg, N.G. and W.E. Johns. Western Boundary Currents. *Rev. of Geophys. Suppl.*, 1311-1334, 1995.

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Dear Sir/Madam:

Enclosed herewith please find 3 copies of the final report on the completion of Grant No. N00014-89-J1139 *Acoustic Velocity Profiling in SYNOP.*

We are grateful to the Office of Naval Research for providing us with funds to carry out this research.

Yours sincerely,

W. E. Johns
Associate Professor

Enclosures

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